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Research on Yarn Diameter and Unevenness Based on an Adaptive Median Filter Denoising Algorithm

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Abstract
In this paper an adaptive median filtering denoising algorithm is proposed to measure yarn diameter and its unevenness. Images of nine different yarn samples were captured using one set of a self-developed yarn image acquisition system. Image separation of the background and yarn sections was conducted using a combination of adaptive median filtering, adaptive threshold segmentation and morphological processing. The noise-free yarn image was used for diameter detection of the subsequent yarn image and the discrimination of the yarn unevenness. Experimental results show that the testing data of yarn unevenness detection based on the adaptive median filter denoising algorithm is very consistent with the data using the traditional method. It is proved that the yarn detection method proposed, based on an adaptive median filter denoising algorithm, is feasible. It can be used to calculate yarn diameter accurately and measure yarn unevenness efficiently, so as to determine the quality of yarn appearance objectively.

Key words: *adaptive median filtering, denoising algorithm, yarn diameter, unevenness, image processing.*

Introduction

The diameter and unevenness of yarn are always considered as the most critical quality parameters for yarn and fabric, especially the appearance quality of yarn and fabric products. They are the most critical parameters for the appearance and style of textile products. Therefore, it is very important to have good quality control of yarn thickness and its variance during the process design and production of textiles [1-3].

The appearance parameters of the yarn mainly include yarn hairiness, fineness, and the unevenness of the diameter. These parameters directly affect physical properties such as the strength, elongation and wear resistance. They also affect the visual appearance of the fabric [4]. The process of the commonly used yarn diameter and unevenness detection method is usually complicated and cumbersome, as it is easily affected by the subjective factors of the judges, making it difficult to evaluate the yarn grade quality objectively [5]. Meanwhile, the measurement method with a capacitance sensor is also easy to be affected by various environmental factors, such as the temperature and humidity of the sample to be tested. Evidently, it is also difficult to evaluate the quality of yarn appearance accurately [6].

In this paper an adaptive median filter denoising algorithm for detecting yarn diameter and unevenness is proposed based on computer image analysis technology. This image-based measurement method has the advantages of removing the subjective factors of the test staff and the impact of the test environment. The digital yarn blackboard image obtained could be used to measure yarn diameter and unevenness objectively. It is a digital method to evaluate yarn quality objectively and realistically [7]. Although there have been related researches in the field of measuring the quality of yarn using computer images [8-10], some improvements are still necessary, such as system adaptivity, robustness of the algorithm, efficiency and reliability. This study, based on an adaptive median filtering denoising algorithm, contributes to the improvement of image analysis algorithms used for yarn diameter and unevenness.

__Table 1.__ Specifications of 9 different yarns.

Yarn No.	Yarn type	Density, tex	Plied of yarn	Tenacity, cN/tex	TMP, T/10 cm
1	Cotton	14.2	1	12.4	128.4
2	Cotton	18.4	1	16.5	144.2
3	Cotton	26.1	1	20.4	139.5
4	Cotton	21.2	2	22.6	155.2
5	Cotton	20.2	1	15.8	129.2
6	Cotton	18.2	1	15.5	142.9
7	Cotton	27.9	1	24.3	160.2
8	Polyester / Viscose (65/35)	26.2	2	23.5	164.5
9	Cotton / Viscose	29.4	1	27.8	169.4

Yarn image acquisition

This experiment used an Epson V700 Photo Scanner (Shenzhen zhisheng technology co. LTD, Japan), a YG381 Shaker Blackboard Machine (Ningbo Textile Instrument Factory, China), a YG136 automatic yarn evenness tester (Ningbo Textile Instrument Factory, China), a "QUICK START Motor" (Shanghai gantuo trading co. LTD, Japan), an NXP Drive Motor Controller (Dongguan changwang electronics co. LTD, Holland), and a D60B Power Supply (Fuzhou chengyue automation equipment co. LTD, China).

The Epson V700 Photo Scanner (Shenzhen zhisheng technology co. LTD, Japan) was connected to the computer via a USB 3.0 cable. The resolution of the scanner was set at 1200 dpi. The actual size of the Yarn Blackboard was 25 cm × 14 cm. Images for 9 different yarn sizes were taken, with a resolution of 500 dpi × 500 dpi, shown in ***Figure 1***. Specifications of the yarns are shown in ***Table 1***.

Yarn image processing

Interference factors, such as system noise, insufficient exposure intensity etc., will cause a certain difference between the image acquired and the original object during the process of image formation and processing. They can result in the difficulty of image processing and analysis. Image preprocessing can remove the background noise and effectively retain edge information of the yarn trunk surface [11]. Useful features of yarns could be extracted after the combination of image preprocessing, including greyscale conversion, histogram equalisation, adaptive median filtering, adaptive threshold segmentation and morphological processing [12].

The principle of pre-treatment area selection is that the hairiness areas selected should be complete with good contrast, and the yarn images selected can basically represent the overall morphological characteristics of the yarns [13]. The advantage of yarn image section can reduce the algorithm cost of image processing and minimise the interference of the environment with the image quality, which can accelerate the efficiency of yarn appearance evaluation [14]. The method of yarn image selection is conducted according to a certain procedure. The phenomenon of hairiness located both inside and outside the image frequently exists; however, when the hairiness is located outside the image, it does not really reflect the real information of yarn during the detection, and therefore it is appropriate to remove these image regions by cropping [15].

Figure 1. *Images of yarn samples.*

Greyscale processing

The original yarn image used for preprocessing in this paper was firstly processed by image conversion from colour to greyscale. After the image conversion, the speed of the image processing and analysis can be improved to reduce the calculation time. In this paper, the original RGB image was converted into a greyscale image by an arithmetic weighting algorithm.

The intensity values of the RGB image corresponds to three channels: R, G, and B, each of which is assigned a certain weight ratio. In the method of arithmetic weighted averaging, the algorithm performs weighted averaging according to the weight ratio assigned. The greyscale value of each pixel could be calculated to obtain a greyscale image.

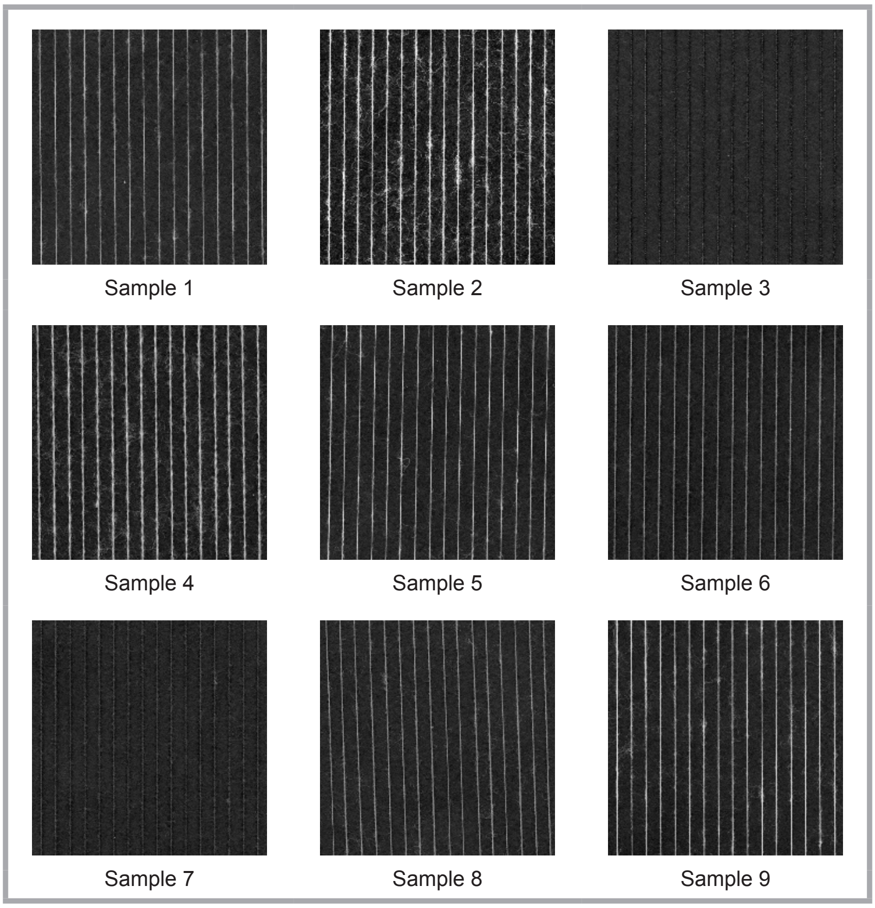

Figure 2. *Grey image of yarns.*

The human sensory system is not sensitive to different colours. Green is the

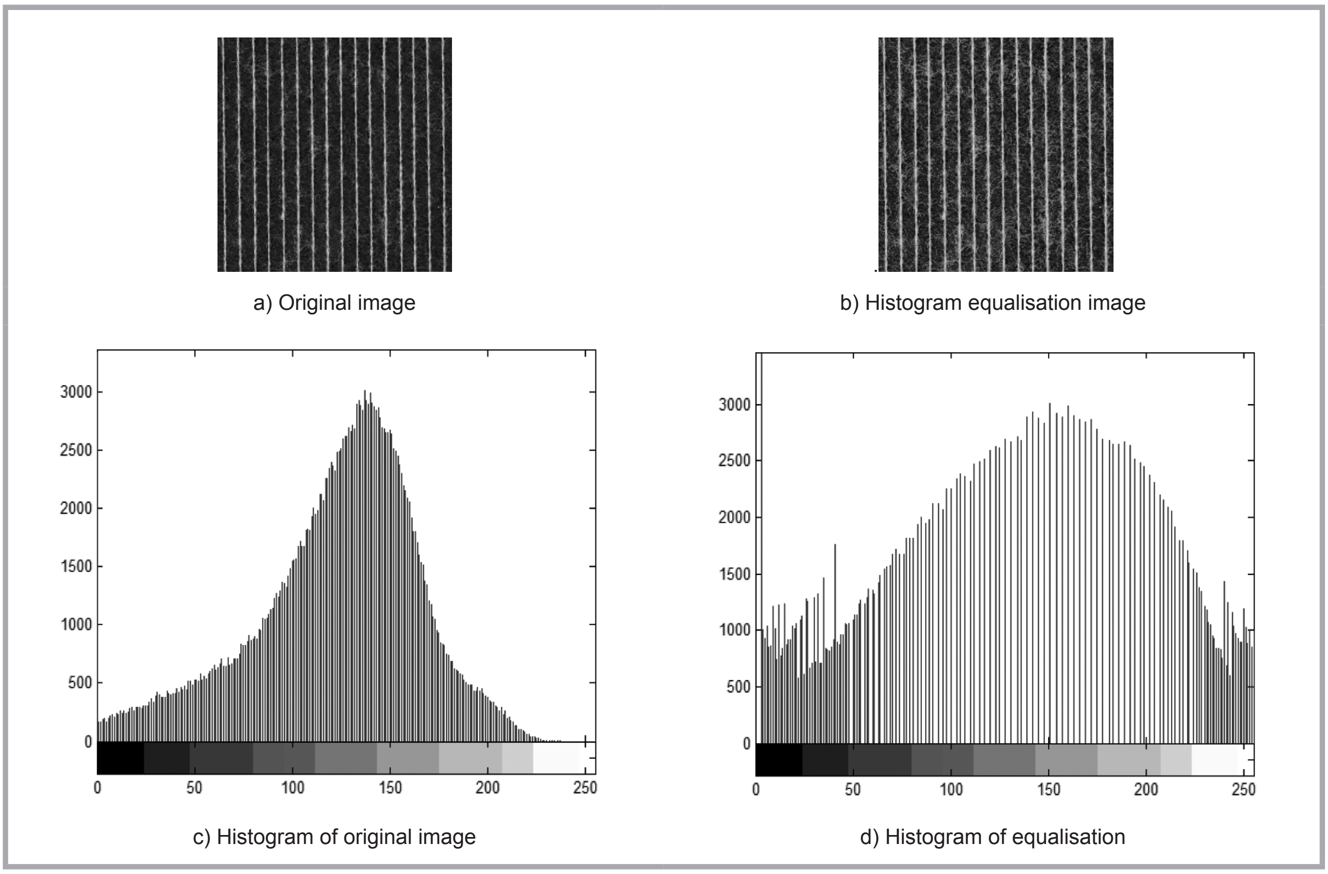

Figure 3. Yarn image before and after histogram equalisation.

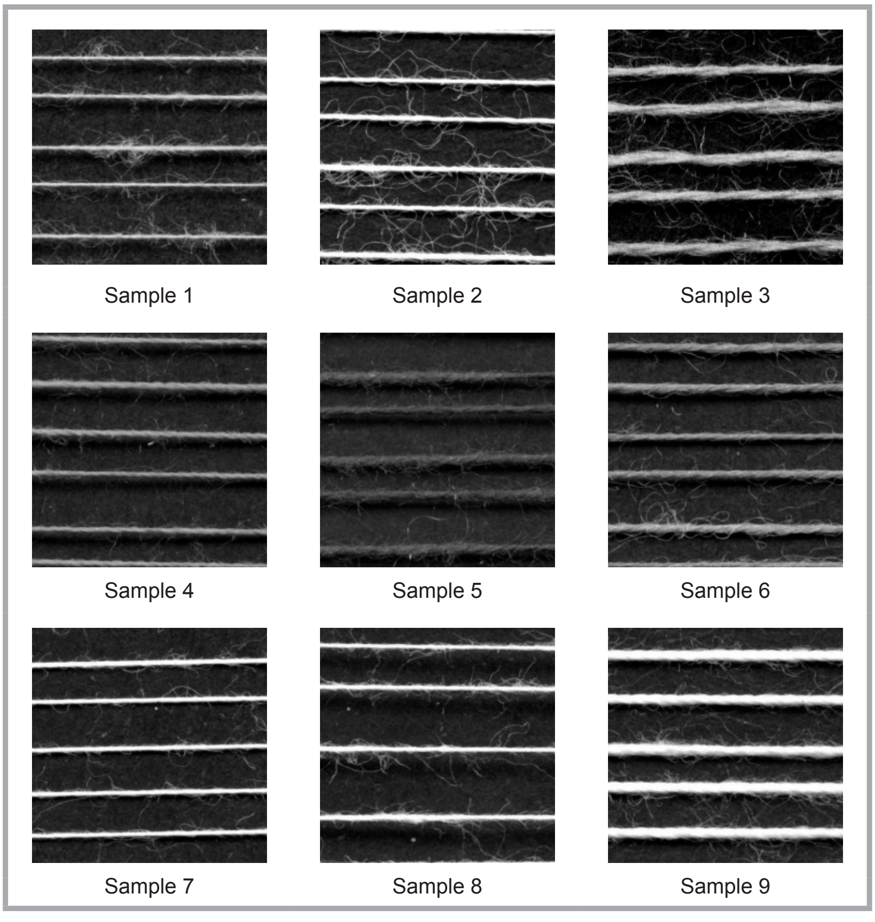

Figure 4. Yarn image after common median filtering.

most sensitive colour for people, with blue slightly sensitive than green [16]. Therefore, it is possible to increase the proportion of the G channel and slightly reduce the proportion of the B channel in the mapping function. A more reasonable greyscale image can be obtained by the mapping function of the following ***Equation (1)***.

$$H = 0.2989R + 0.5870G + 0.1140B \quad (1)$$

Where, H = the grey value of the pixel in the yarn image, and R, G, and B are the luminance values of red, green, and blue in the colour image, respectively. ***Figure 2*** shows a greyscale image after greyscale conversion of the image acquired by the scanner.

Grey scale adjustment

Th yarn samples and yarn standard templates were placed on the scanner glass platform for image scanning. During the process of colour image acquisition, factors such as scanner parameters and illumination problems may lead to unclearness or an uneven grey scale (darker or bright) of the yarn image. The contrast between the yarn and the background in the image is not obvious enough, due to existence of invalid hairiness grey information [17]. Greyscale correction can be used to improve the contrast of the image and is a means of image enhancement that increases the dynamic range.

The original image of the yarn, shown in ***Figure 3.a***, is not clear, and the contrast between the yarn and the background is not obvious enough. After histogram equalisation, the contrast between the yarn and the background could be enhanced, as shown in ***Figure 3.b***. The yarn hairiness in the image becomes clear, and some details that are not obvious in the original image can be observed. The reason is that the grey level interval could be enlarged after the histogram equalisation. The new grey level interval is close to the normal distribution. This method can improve the accuracy of subsequent image analysis.

Adaptive median filtering

The greyscale image after background elimination needs to be denoised and then the image processed using the threshold segmentation algorithm. This operation can eliminate the interference of hairiness and noise, as a result of which segmentation of the yarn image is better [18].

Observing the image processed by the median filter in ***Figure 4***, it can be seen that the edge of the yarn image processed is blurred. The image is distorted relative to the original one.

After adaptive median filtering, the yarn core is better preserved, and interference information is better separated from the yarn. Therefore, this paper proposes a new denoising method – adaptive median filtering denoising which can solve the problem of blurred images. The adaptive median filter is mainly used in the following two steps to process the image.

Firstly, determine the maximum radius of the filter, and then use an appropriate radius r of the image filtering. Calculate the pixel grey I_{min}, I_{max}, I_{med} at the current filter radius, then determine whether I_{med} is between [I_{min}, I_{max}], and if so [I_{min}, I_{max}], reduce the filter radius r, otherwise continue to expand the current filter radius r until it equals the maximum filter radius. Secondly, if the current pixel being processed is $I_{mg}(i, j)$ between [I_{min}, I_{max}], then output the current pixel; otherwise output pixel I_{med}. In this paper, a filter radius of r = 3 was used in the experiment. When r = 3, the de-noising effect of the images is desirable; when r is too big, yarn body images will be eliminated as noise, and when r is too small, the de-noising effect is not ideal. De-noising images for filter radius r = 3 are shown in ***Figure 5***.

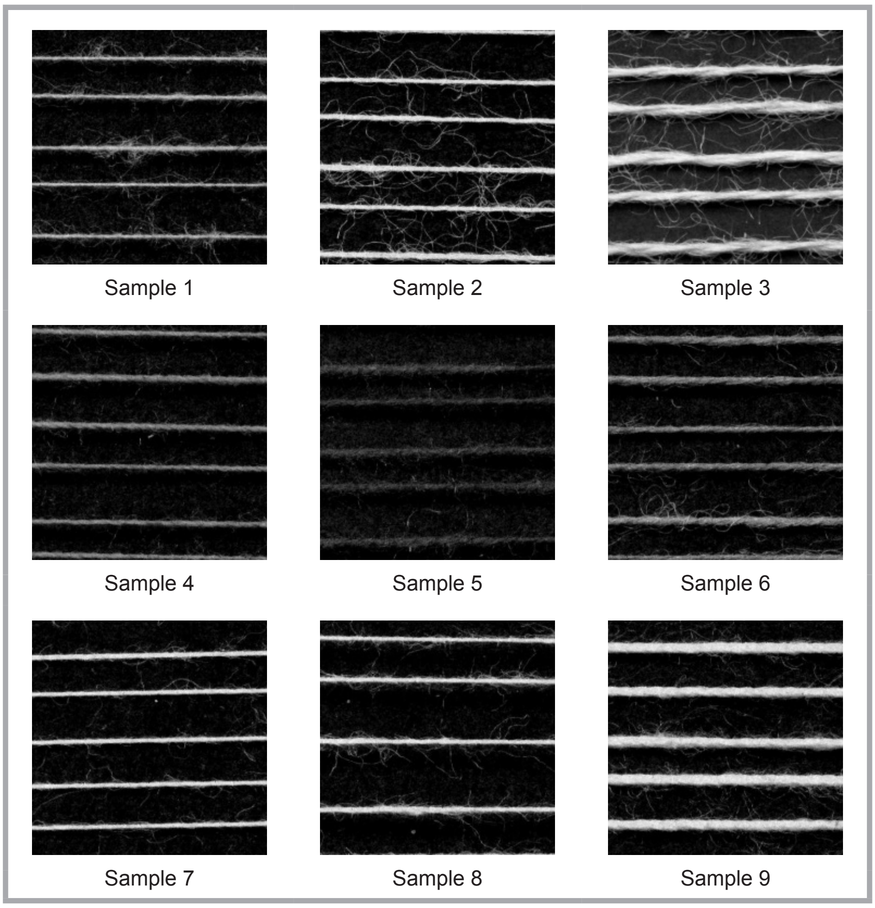

Figure 5. *Yarn image after adaptive median filtering.*

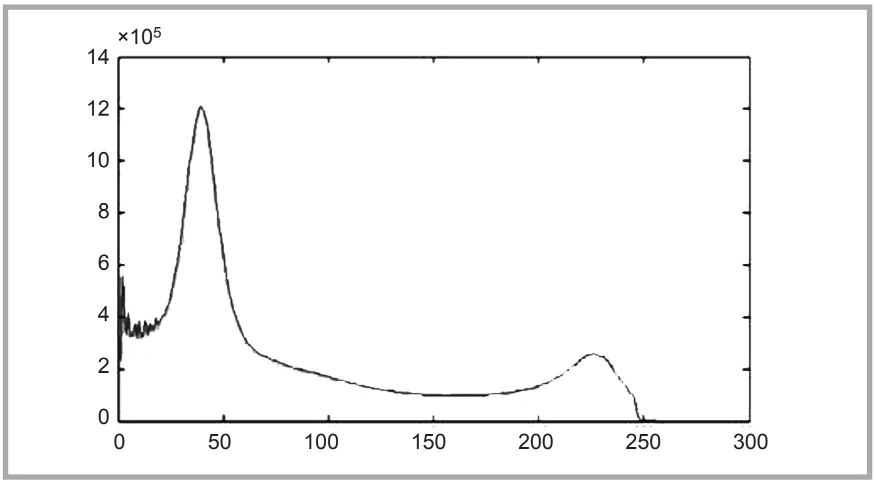

Figure 6. *Grey histogram of yarn image.*

Adaptive threshold segmentation

The yarn is bright and the background dark in the yarn image, which can represent the level of grey. The bimodal method is suitable for an image with a strong contrast between the background and the target, which is suitable for processing the image above. ***Figure 6*** is a grey histogram of the images. The left peak in the histogram represents the darker background, and the right peak – most grey levels in the yarn. The presence of troughs between the two peaks is due to the small number of pixels between them near the yarn boundary. Under normal circumstances, the valley bottom is selected as the grey threshold. From the grey histogram, it can be observed that

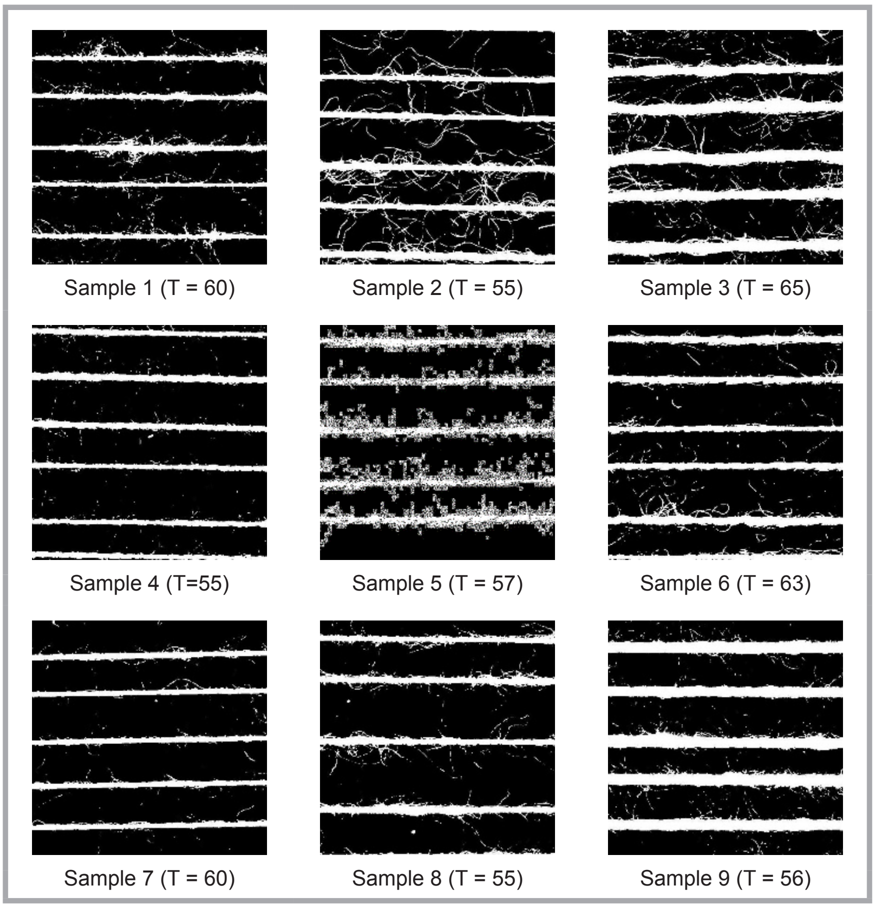

Figure 7. *Yarn images after adaptive threshold segmentation.*

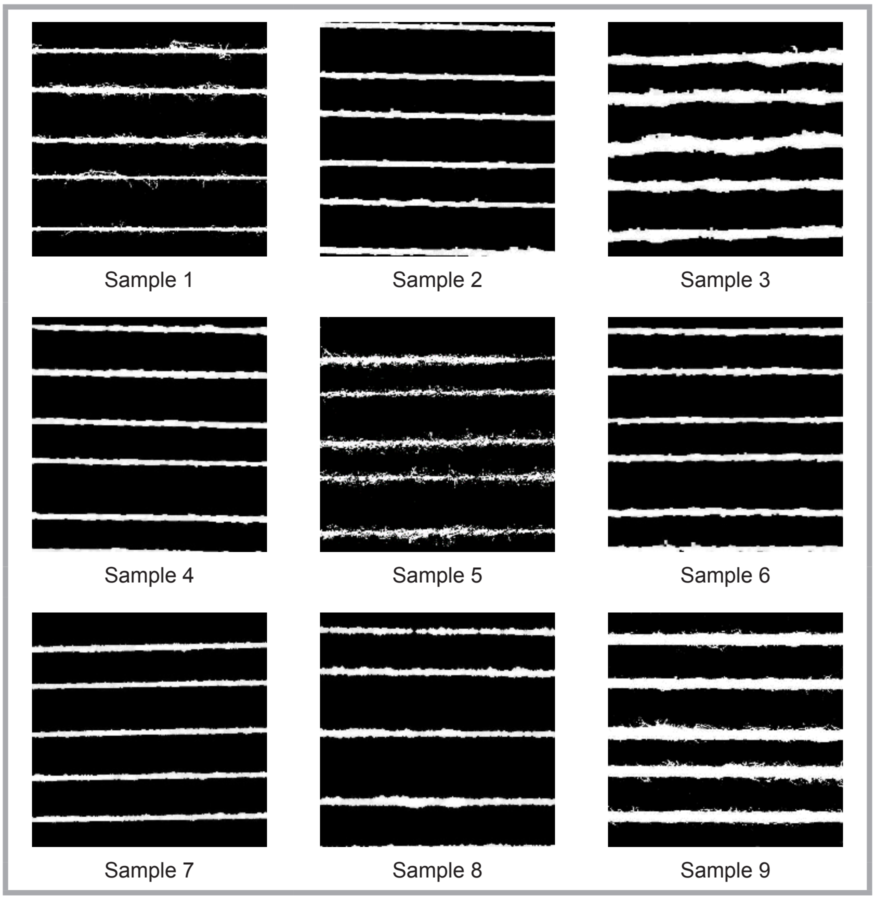

Figure 8. *Morphologically processed yarn image.*

there are many small peaks and valleys on the curve. The value of the valley is not easy to be determined, as it is always disturbed by noise. The minimum value is usually not treated as the expected threshold, since it deviates from the expected value [19-20].

In this experiment, an improved threshold segmentation method is proposed which chooses a position between two peaks, such as the midway position between them. Generally, to reduce noise interference, the selection of the peak value is more reliable than the valley floor, because the peak value represents the typical value inside and outside the region. Experiments show that the image segmentation effect is more ideal and the yarn core image clearer when the improved method is used for threshold segmentation.

Morphological processing

After the yarn image is divided by threshold segmentation, the hairiness of the yarn is not completely eliminated. According to the definition of the drilling operation, the process of corrosion treatment and expansion treatment is called the drilling operation. The function of the opening operation is to eliminate small objects and large smooth objects without changing the area of the large ones. Its function principle is to use structural element B to open the operation to image A.

Experimental results and data analysis

The number of pixels and millimetres in the average diameter of each yarn is converted by the resolution. According to the definition of the resolution, it refers to the number of pixels per inch. Since 1 inch is equal to 25.4 mm, we get ***Equation (2)***.

$$1 \text{ pixel} \approx 1/\text{resolution} \times 25.4 \text{ mm} \quad (2)$$

The resolution used in this paper is set as 1200 dpi. According to ***Equation (2)***, the conversion relationship between the pixels and millimeters is ***Equation (3)***.

$$1 \text{ pixel} = 0.02 \text{ mm} \quad (3)$$

Table 2 shows the average diameter and deviation of the superior yarn and the original yarn sheet measured by the image processing method. It can be seen from ***Table 3*** that the deviation between the image detection result and the capacitance method detection result is small. The conclusions above indicate that the image detection results have a scientific, theoretical basis, consistent with the actual yarn diameter test results. The experiment calculates the single yarn diameter di, the average value and the number of yarns n.

The sliver unevenness calculation formula is as shown in ***Equation (4)***.

$$CV = \frac{1}{\bar{X}}\sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})^2} \times 100\% \quad (4)$$

is the number of pixels in the average diameter of each frame of yarn. *n* the number of lines in the yarn image per frame. and is the number of pixels actually occupied by the yarn.

The results of this experiment were compared to the diameter and unevenness measured by the Uster tester. As illustrated in ***Table 3***, the results of the two methods are very similar, and the accuracy of the image method can be obtained. The maximum deviation rate of the measurement results of the two methods is only 4.4%, and the image measurement process is not limited by environmental conditions and human factors.

Table 2. *Average diameter of 9 different yarns*

Yarn No.	Yarn type	Average diameter, mm	Deviation, %	αm
1	superior yarn 1# yarn	0.165	1.2%	343.2
2	superior yarn 2# yarn	0.160	0.6%	336.2
3	superior yarn 3# yarn	0.158	4.8%	273.1
4	primary yarn with slubs 1# yarn	0.178	6.7%	337.1
5	primary yarn with slubs3# yarn	0.175	1.7%	27.5
6	primary yarn with fine end1# yarn	0.155	1.2%	334.0
7	primary yarn with fine end 3# yarn	0.157	1.3%	304.9
8	primary yarn with neps 1# yarn	0.170	5.2%	321.5
9	primary yarn with neps 3# yarn	0.166	1.2%	312.4

Table 3. *Test results of yarn CV values.*

Yarn No.	Density	Yarn CV values /%		
		Image method	Capacitance method	Deviation ratio
Sample 1	14.21	13.91	14.24	2.3%
Sample 2	18.36	14.15	14.80	4.3%
Sample 3	26.13	22.53	23.37	3.5%
Sample 4	21.17	17.85	18.11	1.4%
Sample 5	20.16	18.80	19.16	1.9%
Sample 6	18.17	16.15	16.90	4.4%
Sample 7	27.81	14.75	15.40	4.2%
Sample 8	26.21	13.91	14.36	3.1%
Sample 9	29.40	17.46	17.95	2.7%

Conclusions

In this paper, nine different types of yarn images were obtained through a self-made yarn image acquisition system. Based on the background of the yarn image, one set of algorithms of adaptive median filtering, adaptive threshold segmentation and morphological open processing is proposed. The resulting clear, noise-free yarn image can be used to detect the yarn diameter and irregularities. The results show that the yarn irregularity detected by the adaptive median filter denoising algorithm is very close to the unevenness detected by the YG136A strip uniformity tester. Therefore, the image yarn detection method proposed, based on the adaptive median filtering denoising algorithm, is feasible. It calculates the yarn diameter and unevenness accurately and efficiently, thus objectively reflecting the appearance quality of the yarn.

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References

1. Hong ZQ. Generating Reasons and Control of Yarn Hairiness[J]. *Cotton Textile Technology* 2006; 34(5): 1-4.
2. Lang J, Lin LT, Zhou J. The Distribution of Yarn Hairiness and the Influence of the Winding on Yarn Hairiness[J]. *Shanghai Textile Science &Technology* 2002; 30(6): 17-19.
3. Li XL. The influence of the yarn hairiness on fabric properties[J]. *Cotton Textile Technology* 2003; 31(4): 63-64.
4. Carvalho V, Cardoso P, Beasley M. Vasconcelos, RM., Soares, FO. Yam hairiness parameterization using a coherent signal processing technique[J]. Sensors and Actuators A. *Physical* 2008; 142(1): 217-224.
5. Fan Y. *The Digital Measurement and Analytic Study of Yarn Appearance* [D]. Shanghai University of Engineering Science, 2015.
6. Dai YP. The *Comparative Study of the Newest Capacitance Evenness Testing Method and Sight Inspection Method about Short Fiber Yarn*[D]. Donghua University, 2015.
7. Chen T, Zhang D. An Improved Adaptive Image De – Noising Algorithm and its Implementation[J]. *Information Technology* 2017; (11): 9-12.
8. Lu JF, Zhang YX. Testing Yarn Evenness of Blackboard using Image Analysis[J]. *Wool Textile Journal* 2003; (4): 53-55.
9. Tang FH, Yu JY, Zhang RY. The Yarn Analysis System Based on Computer Visual Technology[J]. *Journal of Zhongyuan Institute of Technology* 2003;14(1): 15-18.
10. Song XP, Chang T. Study on Computer Recognition of Features of Cotton Yarn Seri plane[J]. *Journal of Xinjiang University* 2004; 21(1): 69-72.
11. Li DB. Image Enhancement Technology in the Application of Security Monitor System. *Super Science* 2017; (7).
12. *Design and Implementation of Processing and Analysis in Mammograms Based on OpenCV*[D]. Beijing Jiaotong university.
13. Su ZB, Huang MY, Jing JF. Image Processing of Yarn Harness Based on Parametric Kernel Graph Cut Method[J]. *Journal of Xi'an Polytechnic University*, 2017, 31(4): 486-494.
14. Liang HW. Study of Method of Reducing and Image Technology Detection Yarn Hairiness[D]. Hebei University of Science and Technology, 2011.
15. Huang MY. *The Research on Yarn Hairiness Detection Algorithm Based on Image Processing*. [D]. Xi'an Polytechnic University, 2017.
16. Chen Y, Liu XY, Jiang Z. Capsule Yinan Defect Recognition Based on RGB and HSV Color Space. *Computer Engineering and Design* 2014; 35(11): 3888-3892.
17. Sun YY, Pan RR, Gao WD. Detection of Yarn Hairiness Based on Digital Image Processing[J]. *Journal of Textile Research* 2013; 34(6): 102-106.
18. Lu M, Liu YP. Binarization Disposal of Image Of Yarn Hairiness and its MATLAB Realization[J]. Shandong Textile Science &Technology 2009; (2): 37-39.
19. Xu YF. Image Segmentation Based on the Genetic Fuzzy C-Mean Algorithm[J]. *Journal of Northwestern Polytechnical University* 2002; (04): 549-53.
20. Chi KL. Detection of Yarn Evenness by Means of Digital Image Processing. Jiang nan university, 2012.

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